~~Strip~~ Surface Mine (I)

RESEARCH ON THE HYDROLOGY AND WATER QUALITY OF WATERSHEDS SUBJECTED TO SURFACE MINING

First

Semi-Annual Technical Report

to

BUREAU OF MINES
U. S. DEPARTMENT OF INTERIOR

from

NORTH APPALACHIAN EXPERIMENTAL WATERSHED
RESEARCH CENTER
AGRICULTURAL RESEARCH SERVICE
U. S. DEPARTMENT OF AGRICULTURE
COSHOCTON, OHIO

and

OHIO AGRICULTURAL RESEARCH AND DEVELOPMENT CENTER
WOOSTER, OHIO

in cooperation with

GEOLOGICAL SURVEY
U. S. DEPARTMENT OF INTERIOR

August 1976

SEMI-ANNUAL TECHNICAL REPORT
August 1976

Title:	Research on the Hydrology and Water Quality of Watersheds Subject to Surface Mining
Sponsor:	Bureau of Mines, U. S. Department of Interior
Participants:	
Grantees:	USDA-Agricultural Research Service North Appalachian Experimental Watershed Coshocton, Ohio (Contract No. J0166054).
	Ohio Agricultural Research and Development Center Wooster, Ohio (Contract No. J0166055).
Cooperators:	Geological Survey U. S. Department of the Interior Columbus, Ohio
	Soil Conservation Service U. S. Department of Agriculture Area and State Offices in Ohio
	Muskingum Watershed Conservancy District New Philadelphia, Ohio
	Coal Mining Companies Bedway Coal Company Central Ohio Coal Company Peabody Coal Company
Cooperation:	Disturbed Lands Area Project Agricultural Research Service U. S. Department of Agriculture Morgantown, West Virginia
	Surface Mine Area Restoration Research Project Forest Service U. S. Department of Agriculture Berea, Kentucky
Duration:	Five years (Initiation, January 1976)

ARS

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Project Leader

James V. Bonta 100%
Project Engineer

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Collaborators

C. R. Amerman	ARS - Hydraulic Engineer
O. L. Bennett	ARS - Supervisory Soil Scientist
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V. T. Ricca	OSU - Professor of Civil Engineering
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Location of Studies:

Headquarters -	USDA-Agricultural Research Service North Appalachian Experimental Watershed Coshocton, Ohio
Satellite Office -	Eastern Ohio Resource Development Center Ohio Agricultural Research and Development Center Caldwell, Ohio
Watersheds -	Coshocton, Muskingum and Jefferson Counties (See Figure 1, page 3).

Watershed Identification:

The watersheds selected for the investigations are shown in Figures 1-6, pages 5-10. The legend for all maps is given in Table 1, page 4. The watershed identification codes with descriptions are as follows:

Identification Code	Description
A06	This 44 acre instrumented, forested watershed is located at the USDA-ARS North Appalachian Experimental Watershed in Coshocton County. The Middle Kittanning Coal outcrops in this drainage (Figure 2).
C06	This 51 acre forested watershed is associated with the Middle Kittanning (No. 6) Coal and is located in southeastern Coshocton County (Figure 3).
M09	This 43 acre pasture watershed is associated with Meigs Creek (No. 9) Coal and is located in the southeastern part of Muskingum County (Figure 4)
J08	This 47 acre forested watershed is associated with the Pittsburgh (No. 8) Coal and is located in southwestern Jefferson County (Figure 5).
J11	This 30 acre mixed pasture and forested watershed is associated with the Waynesburg (No. 11) Coal and is located in southwestern Jefferson County (Figure 6).

Watershed A06 will not be mined. The other four watersheds will be mined.

The instrumentation and data codes are listed in Appendices of the project Research Plan and Activities (July 1976). Instrumentation networks are shown in Figures 2-6, pages 6-10.

TABLE I. LEGEND FOR MAP SYMBOLS

NATURAL SPRING	
INSTRUMENT PLOT	or
STANDARD PLOT WITH GAGE	
SPRING DEVELOPMENT	
BURIED PIPELINE	- - - - - - - - -
CORE SITE	©
WELL MONITORING THE 2ND AQUIFER	②
SEDIMENT POND	
GAGING STATION	⊗
WATERSHED BOUNDARY	
INTERMITTENT STREAMS	
CONTOUR LINE	——200——
COAL OUTCROP	
APPROXIMATE TOE OF SPOIL	....
SOIL MOISTURE ACCESS TUBE	+

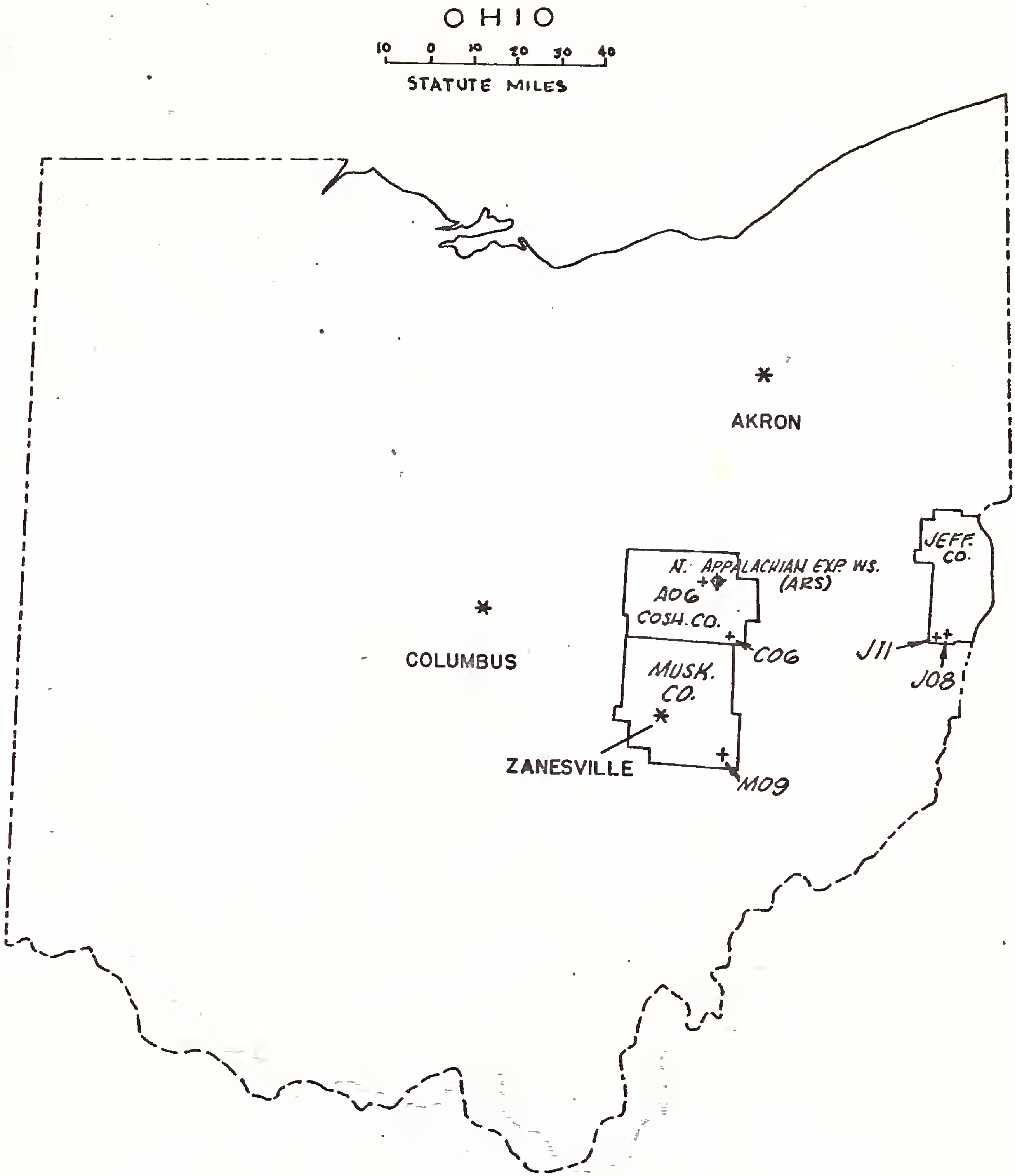

FIGURE 1. LOCATION OF STUDY SITES

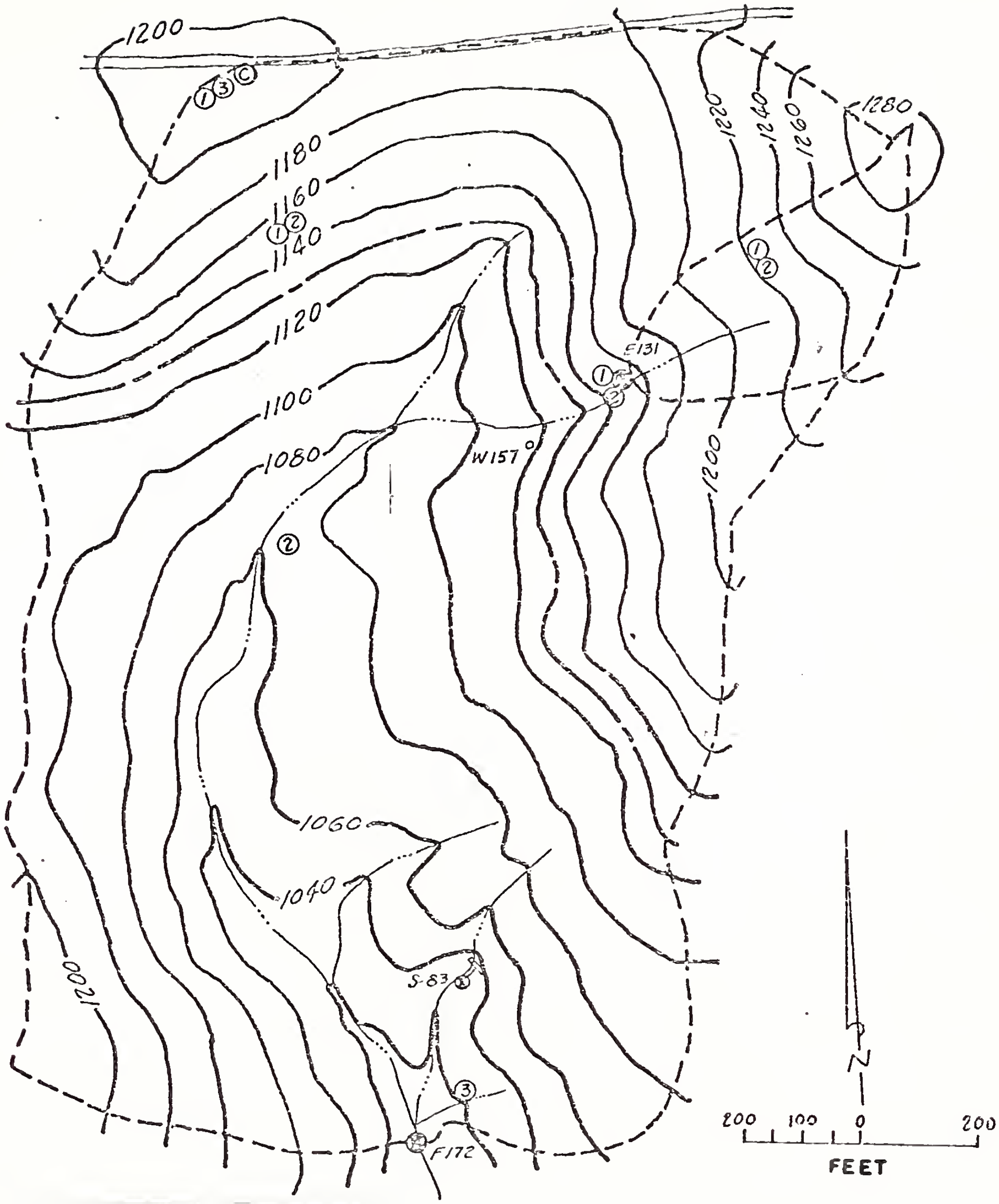

FIGURE 2. AGRICULTURAL RESEARCH SERVICE STUDY SITE (CODE A06), ASSOCIATED WITH THE MIDDLE KITTANNING (NO. 6) COAL, (SECTION 5, WHITE EYES TWP., COSHOCTON COUNTY)

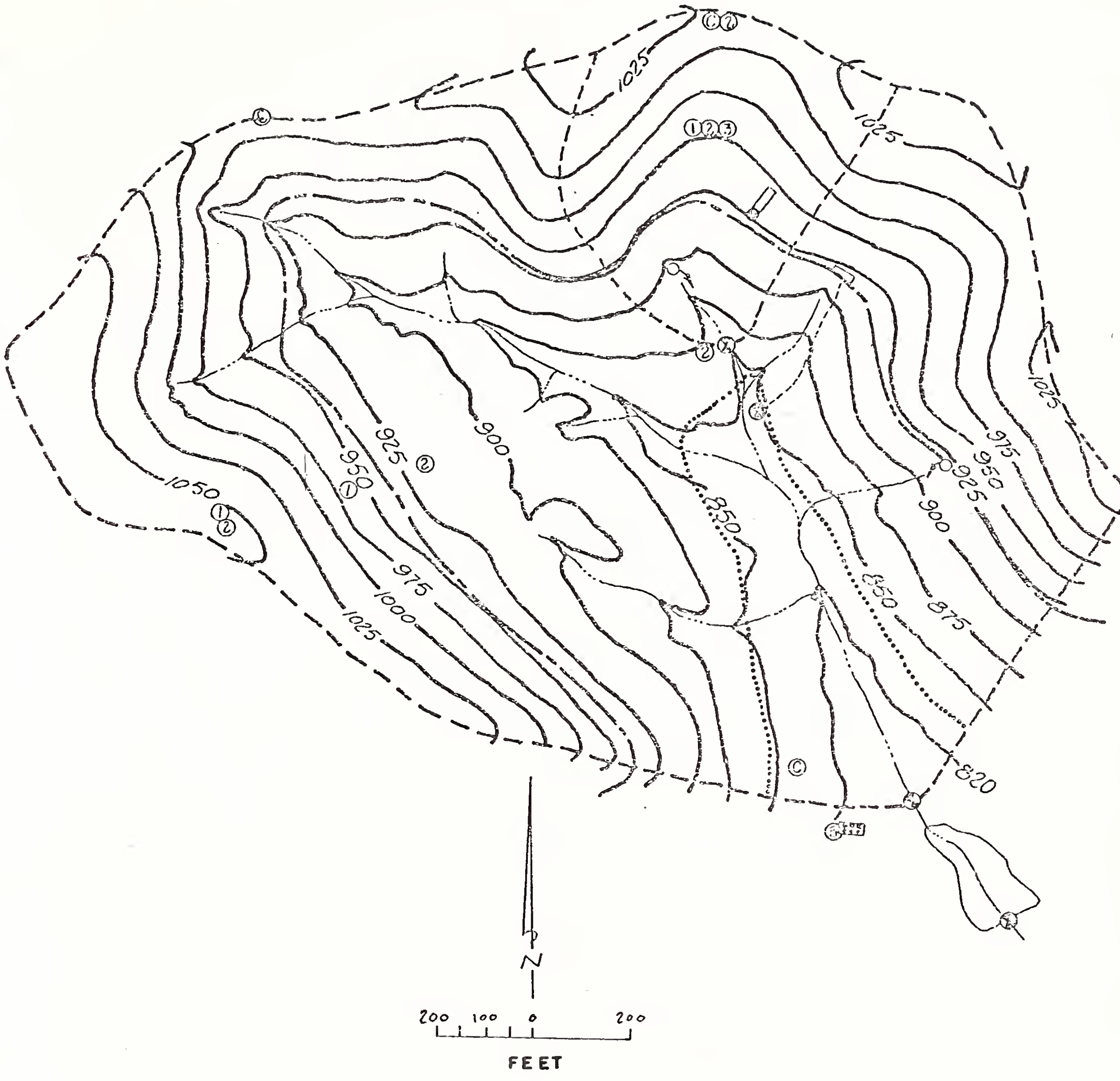

FIGURE 3. COSHOCTON COUNTY STUDY SITE (CODE CO6), ASSOCIATED WITH THE MIDDLE KITTANNING (NO. 6), COAL, (SECTION 22, LINTON TWP.)

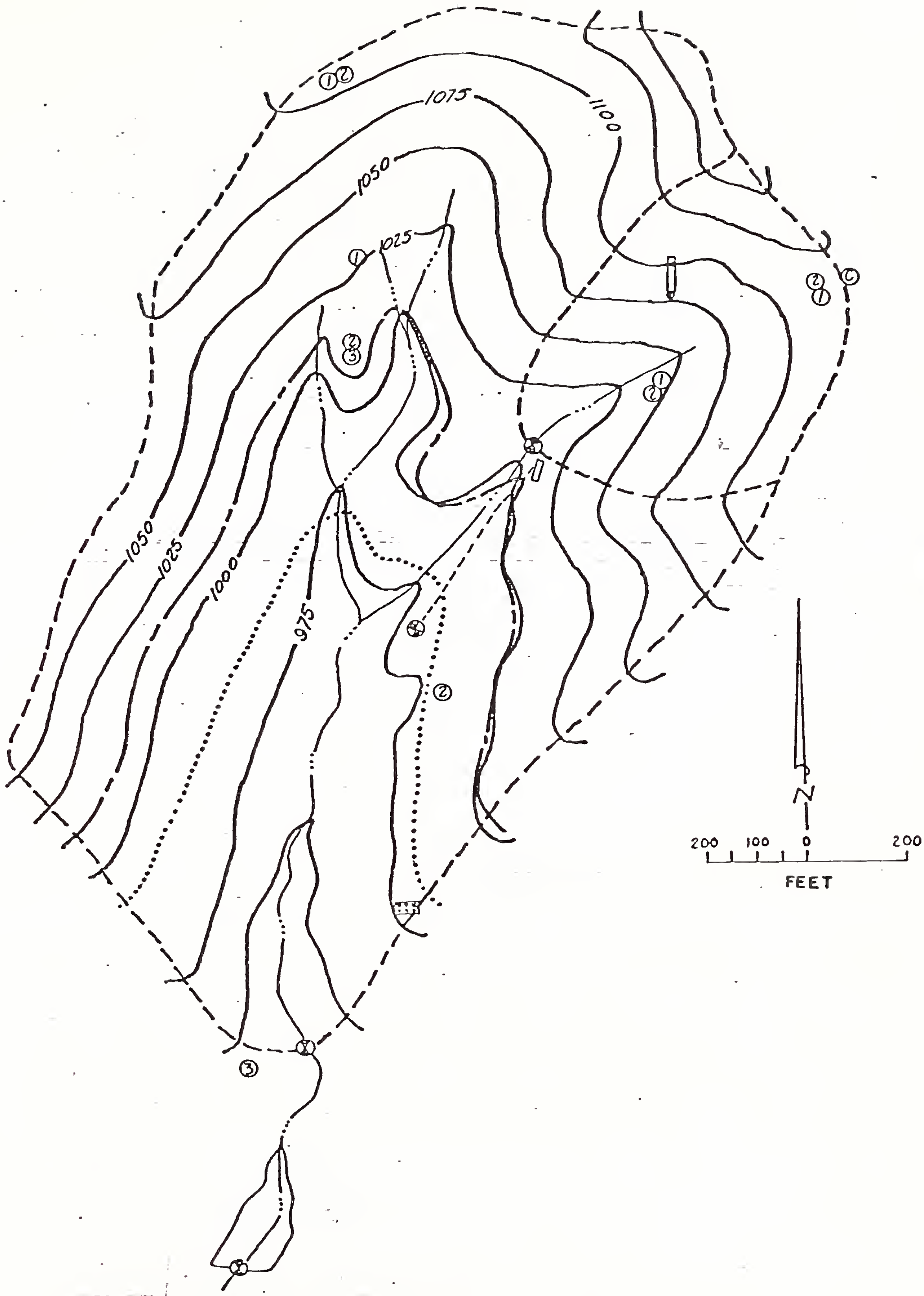

FIGURE 4. MUSKINGUM COUNTY STUDY SITE (CODE M09), ASSOCIATED WITH THE MEIGS CREEK (NO. 9) COAL, (SECTION 17, MEIGS TWP.)

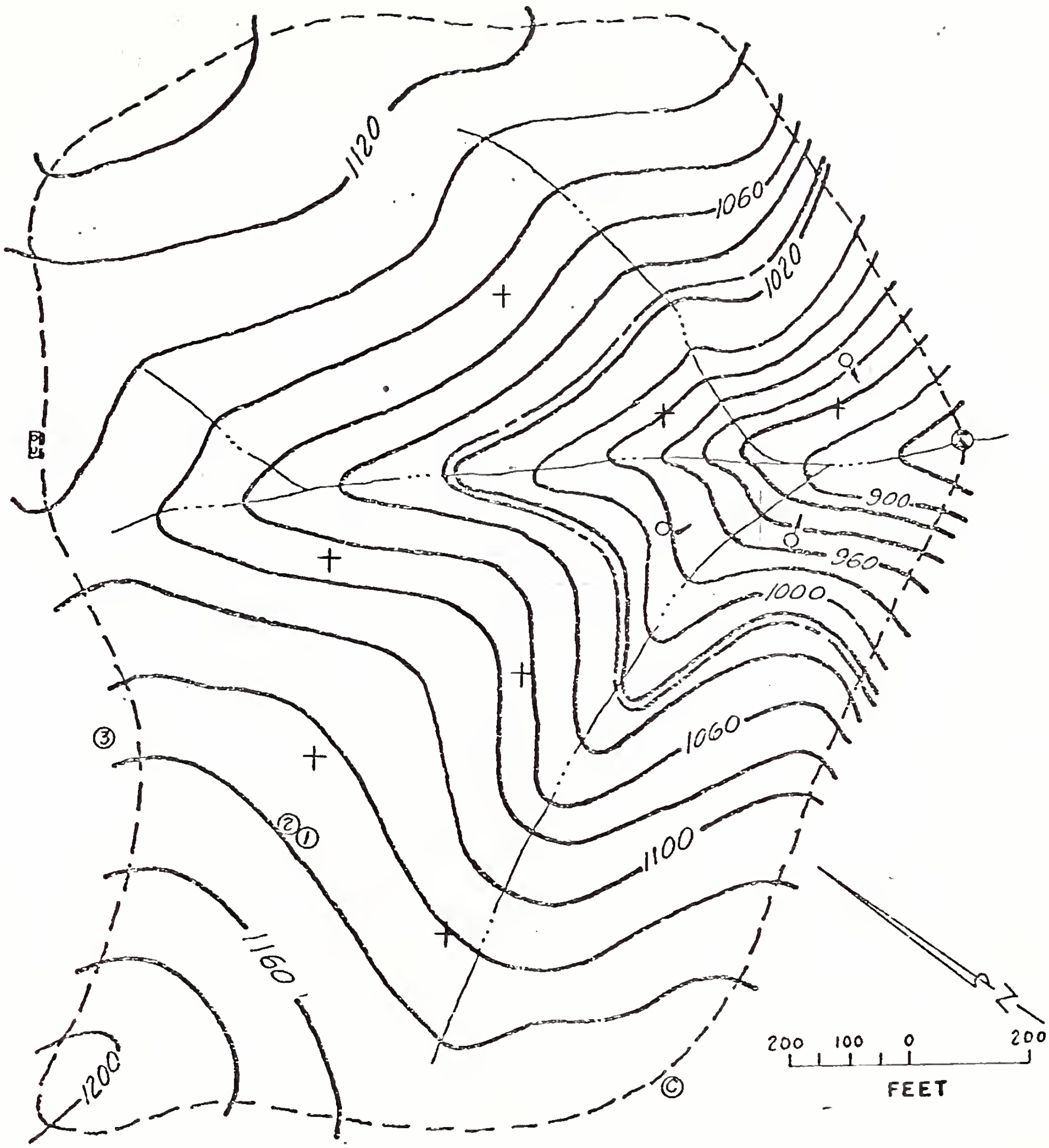

FIGURE 5. JEFFERSON COUNTY STUDY SITE (CODE J08), ASSOCIATED WITH THE PITTSBURGH (NO. 8), COAL, (SECTIONS 12 & 18, MT. PLEASANT TWP.)

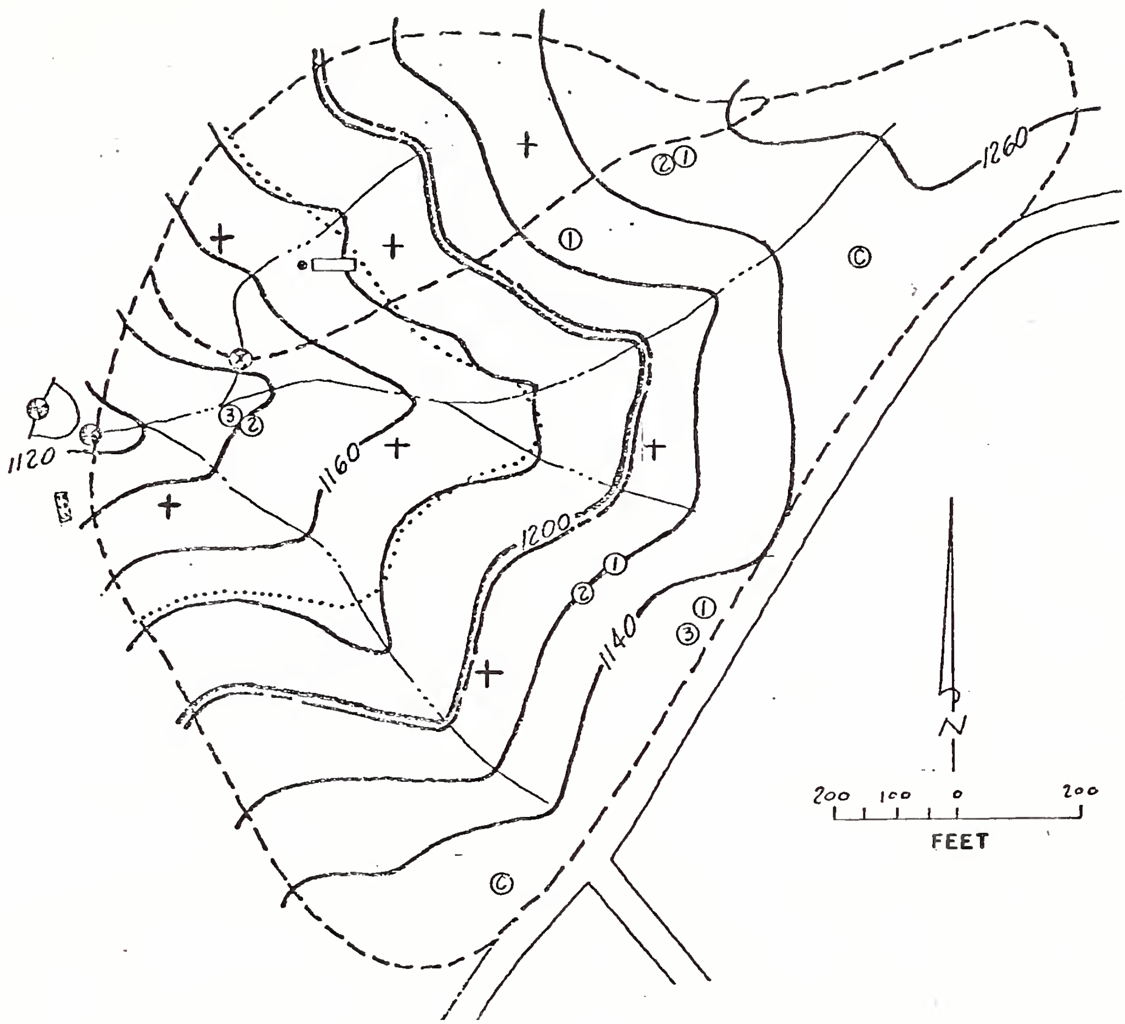

FIGURE 6. JEFFERSON COUNTY STUDY SITE (CODE J11), ASSOCIATED WITH THE WAYNESBURG (NO. 11) COAL, (SECTION 34, MT. PLEASANT TWP.)

Research Activities*

Task Assignments

Objective 1.	Tasks 1, 2, 3, 4, & 6	(ARS)	SM 1-01
	Tasks 4 & 6	(OARDC)	SM 1-02
	Tasks 5 & 6	(OARDC)	SM 1-03
Objective 2.	Tasks 1, 2, 4, 5, 6 & 7	(OARDC)	SM 2-01
	Task 3	(USGS)	SM 2-02
	Task 7	(ARS)	SM 2-03
Objective 3.	Tasks 1, 2, 3, 4, 5, 6 & 7	(USGS)	SM 3-01
Objective 4.	Tasks 1, 2 & 3	(ARS)	SM 4-01
Objective 5.	Tasks 1, 2, 3, & 4	(OARDC)	SM 5-01
Objective 6.	Tasks 1 & 2	(ARS) (OARDC) (USGS)	SM 6-01

*Organization responsible for tasks under each objective is denoted by letters in parenthesis: letter SM designates "surface mining" project; first numerical code designates project objective number; and last two digit code is the number of the activity under the objective.

Progress Report

The progress report for each task covering the reporting period is incorporated under the project objective in the following reports by Research Activities:

RESEARCH ACTIVITY
(Semi-Annual Report, August 1976)

(ARS) SM 1-01
(OARDC) SM 1-02
(OARDC) SM 1-03

Title:	Research on the hydrology and water quality of watersheds subjected to surface mining
Personnel Involved:	(Noted with Tasks)
Initiation Date:	July 1975
Termination Date:	January 1981
Objective 1:	Obtain complete hydrologic and water quality data from at least three watersheds, 40-80 acres in size, for four years with one year of data obtained prior to surface mining, and from erosion and treatment plots for three to four years, and analyze the data.

(Deviations from Objective 1 are as follows: There are five study watersheds, four of which will be mined, and one will not. These sites are shown in Figures 1-6, pages 5-10. Small subwatersheds will be monitored within sites A06, M09, and J11 prior to mining and sites C06, M09 and J11 post mining.)

Task No. 1: (James V. Bonta and W. Russell Hamon, ARS)

Install flumes and water samplers at the outlet of each study watershed; weirs to measure spring flows; soil moisture access tubes; and meteorological equipment (ARS).

Progress Report: Planned instrumentation network for the study watersheds are shown in Figures 2-6, pages 6-10.

To date, two of the watersheds (C06 and M09) to be mined are almost fully instrumented:

The C06 site has been instrumented since January, 1976 to monitor the hydrologic and meteorologic parameters. The instrumentation includes:

1) a temporary 2.5 feet H-flume at the watershed outlet;

2) a 9" HS-flume for springflow;

3) soil moisture access tubes (19 in number);

4) 2 precipitation gages, one shielded and one unshielded;

5) 1 hygothermograph and weather screen; and

6) 1 anemometer

In addition to data obtained by these instruments, water quality grab samples have been obtained periodically.

Currently, the drop-box weir that will replace the 2.5 foot H-flume and an automatic water quality sampler are being fabricated.Also, a data logger has been ordered for automatic collection of all the parameters listed earlier. A reservoir flow measuring device is currently being designed along with its water quality sampler. When this instrumentation is installed, the site will be fully operational. Plot sites have also been located in the vicinity of the C06 watershed. The scheduled start of land clearing for mining is October, 1976.

The M09 site has been instrumented for hydrologic and meteorolgic data collection since May, 1976. The instrumentation includes:

1) a drop-box weir at the watershed outlet;

2) a 9" HS-flume for springflow;

3) a 3-foot H-flume at the small watershed site;

4) soil moisture access tubes (17 in number);

5) 2 precipitation gages, one shielded and one unshielded;

6) 1 hygrothermograph and instrument shelter;

7) 1 anemometer; and

8) 1 water quality rain gage.

In addition to the data collected from these instruments, several water quality grab samples have been obtained from the outlet weir and small watershed flume.

Currently, automatic water quality samplers are being fabricated for the outlet weir and the small watershed flume (at the M09 site). A reservoir flow measuring device and its water quality sampler are currently being designed. A data logger has been ordered for automatic collection of all the parameters listed earlier. When this instrumentation is installed, the M09 site will be completely operational. The start of land clearing and mining is scheduled for early 1977.

The A06 site is in the same stage of operation as the C06 and M09 sites. Hydrologic data have been collected since July, 1975 with the instrumentation that was installed in 1966. Water quality grab samples have been collected periodically from the outlet weir.

Plans for A06 include the installation of soil moisture access tubes, an automatic water quality sampler at the outlet and small watersheds (samplers being fabricated), and installation of additional rain gages. Meteorologic data to be used with A06 are being collected as part of the ongoing ARS program at the North Appalachian Experimental Watershed.

The J08 and J11 sites have not been instrumented. Only the soil moisture access tube plans have been finalized. Weir structure design is currently underway for each site. Hydrologic instrumentation has been received and calibrated, and is ready for use. Scheduled mining of these watersheds is in late 1977 or 1978.

Task No. 2: (James V. Bonta and W. Russell Hamon, ARS)

Install weirs and water samplers on sediment ponds and water measuring and sampling equipment on erosion and treatment plots (ARS).

Progress Report: Installation of erosion and treatment plots to begin in October and instrumentation of sediment in early 1977.

Task No. 3: (James V. Bonta and W. Russell Hamon, ARS)

Reinstall flumes, water samplers, and soil moisture access tubes following surface mining. (ARS)

Progress Report: Work on this task to begin following surface mining.

Task No. 4: (James V. Bonta and W. Russell Hamon, ARS; Faz Haghiri and John Page, OARDC)

Obtain water flow measurements and collect water and sediment samples (ARS-OARDC), and analyze samples (OARDC) following installation of field equipment.

Progress Report: During the period November 1975 - July 1976, runoff measurements and water sampling were operative at the main weirs at sites A06 and C06 and, during the period May - July 1976, the main weir and small watershed flume were operative at the M09 site.

During the four month period following the initiation date of the contract between OARDC and the Bureau of Mines, an analytical chemistry laboratory for water and sediment analyses was established at OARDC, Wooster. This laboratory is now equipped with instruments, such as atomic absorption, inductivity coupled argon plasma (for multi-element determinations of trace metals), color comparator, continuous flow centrifuge, etc., for determinations of various parameters in water and sediment samples. This laboratory is assigned exclusively for conducting research work under this contract. While this laboratory was being instrumented, runoff water and baseflow water samples (grab samples) from the main weir at watershed sites A06 and M09 were obtained and shipped to USGS Central Laboratory in Albany, New York for chemical analyses. The data on water quality parameters for samples obtained during November 1975 through March 1976 from the above sites are shown in Tables 1, 2, 3 and 4.

Subsequent samples have been and are being analyzed at the OARDC (Wooster) laboratory.

Water samples (runoff and baseflow) from M09 and C06 watershed sites during May through June 1976 were collected and prepared for analyses. A schematic of the procedure for treatment of water samples in the laboratory for measurement of the various water quality parameters is shown on the schematic (next page).

The data on various water quality parameters for C06 and M09 (grab samples) are shown in Tables 5-8. Since the quantities of sediment samples separated from the water phase were too small for chemical analyses, no data on the chemical composition of the sediment phase will be reported at this time. However, the sediment samples obtained from each of the above sites will be combined with their corresponding future samples from C06 and M09 sites. When sufficient quantities of sediment are collected, composite samples will be used for chemical analyses.

Schematic of Procedures for Treatment of Water Samples

Water + Sediment Samples

- A. Raw Untreated (avoid disturbing any sediment)
  - a. Aliquot for acidity, alkalinity, bicarbonate, and CO_2
  - b. Aliquot (store at 0-4C) for nitrate and ammonia N
  - c. Aliquot (store in glass bottle at 4C) for phenol
  - d. Aliquot (add 1 ml 10M NaOH and store at 4C) for cyanide
  - e. Aliquot (add 1 ml 10M NaOH and store at 4C) for sulfide
- B. Raw Untreated (suspend the sediment)
  - a. Aliquot for suspended solids
  - b. Filtrate from a. for dissolved solids
- C. Centrifuged Raw Untreated
  - a. Water phase
    - 1. Aliquot for $SO_4^=$, Cl^-, and F^-
    - 2. Aliquot for dissolved solids
    - 3. Acidify the remaining water with HNO_3 (at 3.00 ml/lit)
      - 3.1 Aliquot for Al, Sb, Ba, Cd, Ca, Cr, Fe, Pb, Mg, Mn, Ni, P, Ag, Na, Sr, and Zn
      - 3.2 Aliquot for Hg
      - 3.3 Aliquot for As
      - 3.4 Aliquot for Cr^{+6}
      - 3.5 Aliquot for Se
  - b. Sediment phase
    - 1. pH
    - 2. Pass through a 2 mm non-metallic sieve
      - 2.1 Aliquot for Hg
      - 2.2 Aliquot for $SO_4^=$
      - 2.3 Aliquot for TOC
      - 2.4 Aliquot for Al, Cd, Ca, Cu, Fe, Pb, Mg, Mn, Ni, P, Na, Sr, and Zn

Table 1. Water Quality Analyses

Sampling site: Weir at C06
Source: Baseflow water
No. of samples: 5

Parameters	Unit	Range	Average
Acidity			
Alkalinity	mg/l. ($CaCO_3$)	35-49	42
Aluminum*	μg/l	100-21,000	7500
Ammonia	mg/l	0-.17	0.05
Antimony*	μg/l	0-1	0.6
Arsenic*	μg/l	0-2	0.6
Barium*	μg/l	0-200	66
Bicarbonate	mg/l	18-60	40
Cadmium*	μg/l	0-1	0.3
Calcium	mg/l	11-23	17
Carbon dioxide	mg/l	24-27	25
Chloride	mg/l	2.4-3.3	2.8
Chromium*	μg/l	0-10	6.7
Color**		1-210	45
Copper*	μg/l	0-20	10
Cyanide	mg/l	0-.01	0.005
Flouride	mg/l		0.01
Hardness*	mg/l	41-92	69
Hydrogen sulfide	mg/l	0	
Iron	μg/l	40-140	88
Iron*	μg/l	280-34,000	7458
Lead*	μg/l	2-21	9
Magnesium	mg/l	4-8.5	6.3
Manganese	μg/l	80-210	140
Manganese*	μg/l	90-1100	354
Mercury*	μg/l		<0.5
Nickel*	μg/l	3-35	23
Nitrate	mg/l	.04-.40	0.22
pH (Field)		6.1-6.7	6.4
Phenols	μg/l	0-2	0.6
Phosphorus*	mg/l	.01-.56	0.2
Selenium*	μg/l	0-2	0.6
Silver*	μg/l	0-1	0.3
Sodium	mg/l	2.9-4.2	3.5
Sp. Conductance	μmhos	115-215	169
Strontium*	μg/l	50-150	100
Sulfate	mg/l	34-45	41
Temperature	C°	1-14	6
Zinc*	μg/l	20-110	53
Flow rate	CFS	.03-.21	0.11

* Unfiltered
** 0-500 color units

Table 2. Water Quality Analyses

Sampling site: Weir at C06
Source: Runoff water
No. of samples: 3

Parameters	Unit	Range	Average
Acidity			
Alkalinity			
Aluminum*	µg/l	290-1600	733
Ammonia	mg/l	0.03-.05	0.04
Antimony*	µg/l	0-2	1
Arsenic*	µg/l	1-3	1.7
Barium*	µg/l		100
Bicarbonate	mg/l	12-18	15.7
Cadmium*	µg/l	0-1	<1
Calcium	mg/l	11-13	12
Carbon dioxide		10.8-14.4	12.4
Chloride	mg/l	1.8-2.6	2.3
Chromium*	µg/l	0-10	6.7
Color**		21-24	23
Copper*	µg/l	0-10	6.7
Cyanide	mg/l		0
Flouride	mg/l	0.1-0.2	0.13
Hardness*	mg/l	43-50	46
Hydrogen sulfide	mg/l		0
Iron	µg/l	100-590	280
Iron*	µg/l	570-6100	3190
Lead*	µg/l	7-1	3.7
Magnesium	mg/l	3.5-4.8	4.0
Manganese	µg/l	30-100	70
Manganese*	µg/l	50-330	190
Mercury*	µg/l		<0.5
Nickel*	µg/l	4-31	15
Nitrate	mg/l	0.32-1.3	0.65
pH (Field)		6.2-6.4	6.3
Phenols	µg/l	0-1	<1
Phosphorus*	mg/l	0.06-.16	0.1
Selenium*	µg/l	0-1	<1
Silver*	µg/l	0-2	1
Sodium	mg/l	2-2.3	2.2
Sp. Conductance	µmhos	95-118	107
Strontium*	µg/l	20-50	36
Sulfate	mg/l	34-36	35
Temperature	C°	5.0-8.5	6.7
Zinc*	µg/l	40-20	30
Flow rate	CFS	0.70-2.5	1.38
Suspended solids	mg/l	49-1080	408

* Unfiltered
** 0-500 color units

Table 3. Water Quality Analyses

Sampling site: Weir at A06
Source: Baseflow water
No. of samples: 5

Parameters	Unit	Range	Average
Acidity			
Alkalinity	mg/1 ($CaCO_3$)		
Aluminum*	μg/1	210-530	340
Ammonia	mg/1	0.01	<0.01
Antimony*	μg/1	0-2	1
Arsenic*	μg/1		0
Barium*	μg/1	0-100	33
Bicarbonate	mg/1	42-120	69
Cadmium*	μg/1		0
Calcium	mg/1	19-37	27
Carbon dioxide	mg/1	15.9-27.4	21.6
Chloride	mg/1	2.7-5.1	4.0
Chromium*	μg/1		≤10
Color**		1-4	2
Copper*	μg/1	0-10	3
Cyanide	mg/1	0-0.01	<0.01
Flouride	mg/1		0.1
Hardness*	mg/1	75-130	95
Hydrogen sulfide	mg/1		0
Iron	μg/1	50-140	104
Iron*	μg/1	200-980	500
Lead*	μg/1	1-4	2
Magnesium	mg/1	4.8-10	6.9
Manganese	μg/1	60-230	118
Manganese*	μg/1	80-230	124
Mercury*	μg/1		<0.5
Nickel*	μg/1	0-4	1.7
Nitrate	mg/1	0.01-0.69	0.5
pH (Field)		6.2-6.7	6.5
Phenols	μg/1	0-3	1
Phosphorus*	mg/1	0.02-0.04	0.03
Selenium*	μg/1	0-1	<1
Silver*	μg/1	0-1	<1
Sodium	mg/1	3.4-12	6.6
Sp. Conductance	μmhos	185-300	230
Strontium*	μg/1	70-160	100
Sulfate	mg/1	37-55	47
Temperature	C°	1-12	4.6
Zinc*	μg/1	10-30	20
Flow rate	CFS	0.01-0.13	0.07

* Unfiltered
** 0-500 color units

Table 4. Water Quality Analyses

Sampling site: Weir at A06
Source: Runoff water
No. of samples: 3

Parameters	Unit	Range	Average
Acidity			
Alkalinity			
Aluminum*	µm/l	710-10,000	3970
Ammonia	mg/l	0.01-0.06	0.04
Antimony*	µg/l	0-2	1
Arsenic*	µg/l	0-5	<2
Barium*	µg/l	100-200	133
Bicarbonate	mg/l	15-21	17
Cadmium*	µg/l		0
Calcium	mg/l	9-15	12
Carbon dioxide	mg/l	12.0-16.8	14.1
Chloride	mg/l	2.2-2.7	2.4
Chromium*	µg/l	0-10	7
Color**		16-200	108
Copper*	µg/l	0-10	7
Cyanide	mg/l		0
Flouride	mg/l	0.1-0.2	<0.2
Hardness*	mg/l	35-48	47
Hydrogen sulfide	mg/l		0
Iron	µg/l	80-270	173
Iron*	µg/l	1400-18,000	7000
Lead*	µg/l	3-20	13
Magnesium	mg/l	3-5	4.2
Manganese	µg/l	20-110	56
Manganese*	µg/l	70-810	323
Mercury*	µg/l		<0.5
Nickel*	µg/l	7-31	21
Nitrate	mg/l	0.58-1.6	1.1
pH (Field)			6.3
Phenols	µg/l	0-1	<1
Phosphorus*	mg/l	0.08-0.45	0.21
Selenium*	µg/l	0-1	<1
Silver*	µg/l	0-1	<1
Sodium	mg/l	1.1-3.1	2
Sp. Conductance	µmhos	130-176	150
Strontium*	µg/l	40-70	60
Sulfate	mg/l	27-39	34
Temperature	C°	3.5-5.0	4.2
Zinc*	µg/l	10-70	40
Flow rate	CFS	1.1-2.2	1.5
Suspended solids	mg/l	28-43	35

* Unfiltered
** 0-500 color units

Table 5. Water Quality Analyses

Sampling Site: Weir at C06
Source: Baseflow water
No. of samples: 2

Parameters	Unit	Range	Average
Acidity	meq/l	0.059-0.103	0.081
Alkalinity**	mg/l	41-48	45
Aluminum*	μg/l	91-788	440
Ammonia	mg/l	<0.05	<0.05
Antimony*	μg/l	0	0
Arsenic*	μg/l	<40	<40
Barium*	μg/l	26-47	37
Bicarbonate	mg/l	50-58	54
Cadmium*	μg/l	0-8	4
Calcium	mg/l	19-21	20
Carbon dioxide	mg/l	3.2-3.7	3.5
Chloride	mg/l	1.3-1.9	1.6
Chromium*	μg/l	<10-12	<11
Color***			
Copper*	μg/l	0	0
Cyanide	mg/l	0.03-0.06	0.045
Fluoride	mg/l	0.08-0.10	0.09
Hardness* ****	mg/l	76-85	81
Hydrogen sulfide	mg/l		<.3
Iron*	μg/l	129-612	371
Lead*	μg/l	0	0
Magnesium	mg/l	7-8	7.5
Manganese*	μg/l	94-320	207
Mercury*	μg/l	<0.2-8	4
Nickel*	μg/l	0	0
Nitrate	mg/l	0.16-0.64	0.40
pH (Field)			
Phenols	μg/l	<10	<10
Phosphorus*	mg/l	0	0
Selenium*	μg/l	0.1-0.2	0.15
Silver*	μg/l	0	0
Sodium	mg/l	4.0-4.4	4.2
Sp. Conductance	μmhos		
Strontium	μg/l	74-85	80
Sulfate	mg/l	36-42	39
Temperature	C°	15-18.4	16.7
Zinc*	μg/l	0-12	6
Flow rate	CFS	0.0038-0.082	0.0429
Suspended solids	mg/l	5-252	128
Dissolved solids	mg/l	130-141	136

* Filtered
** As $CaCO_3$
*** 0-500 color units
**** $CaCO_3$ equivalent due to Ca and Mg

Table 6. Water Quality Analyses

Sampling site: Weir at MO9
Source: Baseflow water
No. of samples: 1

Parameter	Unit	Quantity
Acidity	meq/l	0.230
Alkalinity**	mg/l	152
Aluminum*	μg/l	8
Ammonia	mg/l	<0.05
Antimony*	μg/l	0
Arsenic*	μg/l	<40
Barium*	μg/l	70
Bicarbonate	mg/l	185
Cadmium*	μg/l	0
Calcium	mg/l	76
Carbon dioxide	mg/l	11.7
Chloride	mg/l	9.2
Chromium*	μg/l	<10
Color***		
Copper*	μg/l	0
Cyanide	mg/l	<0.03
Fluoride	mg/l	0.18
Hardness* ****	mg/l	276
Hydrogen sulfide	mg/l	<.3
Iron*	μg/l	40
Lead*	μg/l	0
Magnesium	mg/l	21
Manganese*	μg/l	17
Mercury*	μg/l	3
Nickel*	μg/l	0
Nitrate	mg/l	0
pH (Field)		
Phenols	μg/l	<10
Phosphorus*	mg/l	0
Selenium*	μg/l	0.2
Silver*	μg/l	0
Sodium	mg/l	6.4
Sp. Conductance	μmhos	
Strontium	μg/l	375
Sulfate	mg/l	45
Temperature	C°	20.6
Zinc*	μg/l	0
Flow rate	CFS	0.01
Suspended solids	mg/l	105
Dissolved solids	mg/l	261

* Filtered
** As $CaCO_3$
*** 0-500 color units
**** $CaCO_3$ equivalent due to Ca and Mg

Table 7. Water Quality Analyses

Sampling site: Small Weir at M09
Source: Baseflow water
No. of samples: 1

Parameter	Unit	Quantity
Acidity	meq/l	0.108
Alkalinity**	mg/l	62
Aluminum*	µg/l	658
Ammonia	mg/l	<0.05
Antimony*	µg/l	117
Arsenic*	µg/l	<40
Barium*	µg/l	51
Bicarbonate	mg/l	75
Cadmium*	µg/l	13
Calcium	mg/l	32
Carbon dioxide	mg/l	6.0
Chloride	mg/l	1.2
Chromium*	µg/l	<10
Color***		
Copper*	µg/l	23
Cyanide	mg/l	<0.03
Fluoride	mg/l	0.19
Hardness* ****	mg/l	101
Hydrogen sulfide	mg/l	<.3
Iron*	µg/l	33
Lead*	µg/l	89
Magnesium	mg/l	5
Manganese*	µg/l	84
Mercury*	µg/l	<0.2
Nickel*	µg/l	99
Nitrate	mg/l	0.65
pH (Field)		
Phenols	µg/l	11
Phosphorus*	mg/l	0.31
Selenium*	µg/l	0.3
Silver*	µg/l	12
Sodium	mg/l	3.2
Sp. Conductance	µmhos	
Strontium	µg/l	136
Sulfate	mg/l	26
Temperature	C°	17.2
Zinc*	µg/l	15
Flow rate	CFS	<0.0021
Suspended solids	mg/l	75
Dissolved solids	mg/l	123

* Filtered
** As $CaCO_3$
*** 0-500 color units
**** $CaCO_3$ equivalent due to Ca and Mg

Table 8. Water Quality Analyses

Sampling site: Weir at M09
Source: Runoff water
No. of samples: 1

Parameter	Unit	Quantity
Acidity	meq/l	0.088
Alkalinity**	mg/l	203
Aluminum*	μg/l	219
Ammonia	mg/l	<0.05
Antimony*	μg/l	146
Arsenic*	μg/l	<40
Barium*	μg/l	75
Bicarbonate	mg/l	247
Cadmium*	μg/l	10
Calcium	mg/l	67
Carbon dioxide	mg/l	4.0
Chloride	mg/l	12.4
Chromium*	μg/l	<10
Color***		
Copper*	μg/l	0
Cyanide	mg/l	<0.03
Fluoride	mg/l	0.19
Hardness* ****	mg/l	243
Hydrogen sulfide	mg/l	<.3
Iron*	μg/l	135
Lead*	μg/l	83
Magnesium	mg/l	18.3
Manganese*	μg/l	41
Mercury*	μg/l	<0.2
Nickel*	μg/l	93
Nitrate	mg/l	0
pH (Field)		
Phenols	μg/l	<10
Phosphorus*	mg/l	0.15
Selenium*	μg/l	0.3
Silver*	μg/l	13
Sodium	mg/l	5.9
Sp. Conductance	μmhos	
Strontium	μg/l	326
Sulfate	mg/l	36
Temperature	C°	21.1
Zinc*	μg/l	10
Flow rate	CFS	0.127
Suspended solids	mg/l	241
Dissolved solids	mg/l	324

* Filtered
** As $CaCO_3$
*** 0-500 color units
**** $CaCO_3$ equivalent due to Ca and Mg

Task No. 5: (Paul Sutton, OARDC)

Application of reclamation treatments to treatment plots and collection of samples and data (OARDC).

Progress Report: An area was selected for the reclamation treatment plots at the C06 watershed site. The area has been mined and reclamation grading partially completed. Areas for the treatment plots will be selected for the M09 and J11 sites this fall.

Task No. 6: (James V. Bonta and W. Russell Hamon, ARS; Faz Haghiri and Paul Sutton, OARDC)

Evaluate the data relative to runoff, erosion, water quality, and reclamation. (ARS-OARDC)

Progress Report: An evaluation of the available data will be part of the Phase 1 (pre-mining) report.

RESEARCH ACTIVITY
(Semi-Annual Report, August 1976)

(OARDC) SM 2-01
(USGS) SM 2-02
(ARS) SM 2-03

Title: Research on the hydrology and water quality of watersheds subjected to surface mining

Personnel Involved: (Noted with Tasks)

Initiation Date: January 22, 1976

Termination Date: January 22, 1981

Objective 2: Characterize the study watersheds and plots, and obtain physical and chemical data for the soils and overburden materials prior to surface mining and for the replaced top soil and underlying spoil material following surface mining.

Task No. 1: (George F. Hall and Neil E. Smeck, OARDC)

Soil mapping and characterization of soils on study watersheds (SCS-OARDC).

Progress Report: The soil mapping has been completed on all the watersheds by James Forshey and Marvin Bureau (SCS). Soil mapping units used were from the state legend. The soils legend and soils mapped are presented in Table 2-1 and the slope and erosion codes in Table 2-2. Soil maps of the watersheds are presented as figures 2-1 through 2-5. Soil mapping units and the legend for sites C06 and M09 were checked by Neil Smeck and George Hall (OARDC).

Task No. 2: (George F. Hall and Neil E. Smeck, OARDC)

Collect samples and conduct analyses of physical and chemical properties of soil materials (OARDC).

Progress Report: Soil sampling sites were selected in the C06 watershed. A total of five sites were selected to represent the five major soils in the watershed. Pits were dug with a back-hoe and by hand and 3 of the soils (Gilpin unit, Coshocton unit and Dekalb unit) were sampled. The other two sites will be sampled in August. Samples were taken from all soil horizons down to bedrock and were transported to the OARDC laboratory at Columbus where analyses will be conducted.

Task No. 3: (Darwin Knochenmus and Kristine Rebulz-Ukayli, USGS)

Obtain geologic cores of study watersheds.

Progress Report: Geologic cores were drilled at each of the five research watersheds. At the C06 site, the core hole was 296 feet deep and penetrated the Conemaugh, Allegheny and Pottsville Series of the Pennsylvanian Period. The coal seams encountered were the Middle Kittanning (No. 6) (2.7 feet), the Bedford Coal (1.6 feet), and the Middle Mercer (0.2 feet). The associated underclays were in all instances of greater thickness (7.0, 2.1, and 1.2 feet, respectively) than the overlying coal seams, and the remainder of the core was composed of the silt, sandstones, and shales commonly found in the rocks of the Allegheny Series.

The M09 core sampled the Monongahela and Conemaugh Series of the Pennsylvanian Period. With a total depth of 299.6 feet, the core passes through three coal seams: the Uniontown (No. 10) (0.6 feet) with an underclay thickness of 0.7 feet, the Meigs Creek, Sewickley (No. 9) coal (4.3 feet) and underclay (5.5 feet), and the Pittsburgh (No. 8) coal (0.6 feet) with associated underclay (4.5 feet). Limestones and limy shales and sandstones are more prevalent in this section of the Pennsylvanian System than found in series cored at the C06 site.

J08 and J11 cores both penetrate the Monongalela with J08 extending upwards into the Dunkard and J11 continuing down into the upper series of the Conemaugh. The J11 core was 300 feet deep and encountered several seams including the Waynesburg (No. 11) coal (4.1 feet), Uniontown (No. 10) (0.2 feet), Sewickley (No. 9) (2.1 feet), Redstone (No. 8A) (0.5 feet), and the Pittsburgh (No. 8) coal (5.0 feet). At this site, little or no thicknesses of underclay were found associated with the coals; instead shales, limestones and limy shales were prevalent. Sandstones were found in the Dunkard Series. The J08 core extended to a depth of 245 feet and sampled mostly shales and limestones similar to those of J11. Two coals, the Sewickley (No. 9) (1.9 feet) and the Pittsburgh (No. 8) (5.4 feet and 1.9 feet broken by shale parting) were found with no associated underclays.

The A06 core reached a depth of 270 feet and was similar to the C06 core in that it pentrated the Allegheny and Pottsville Series of the Pennsylvanian Period. Nothing remained of the Middle Kittanning coal (No. 6) except a 7.7-foot mined-out cavity and 3.8 feet of underclay. Several other seams were encountered including the Brookville (No. 5) (1.0 foot), Tionesta (trace) and the Middle Mercer coal (0.2 foot). The sequences of silts, sandstones, and shales are the same as those found in the C06 core except for the addition of more coal traces and the Putnam Hill limestone (5.2 feet), Brookville coal, and underclay (2.2 feet).

Task No. 4: (George F. Hall and Neil E. Smeck, OARDC)

Determine chemical and physical parameters on geologic cores (OARDC).

Progress Report: After study of the description of the geologic cores and the cores themselves, selected samples were taken from several of the cores for analysis at the OARDC soil laboratory. In this initial sampling emphasis was placed on sampling of the coal units and the shale above and below the coal. Results of the analyses will be used as a guide for further sample selection.

Task Nos. 5 and 6: (George F. Hall and Neil E. Smeck, OARDC)

(See Research Plan and Activities)

Progress Report: Work will proceed on these tasks following mining.

Task No. 7: (George F. Hall and Neil E. Smeck, OARDC: James V. Bonta and W. Russell Hamon, ARS)

Measure water infiltration and percolation characteristics of watershed soils and of reclaimed spoil material (ARS-SCS-OARDC).

Progress Report: The ARS rainfall simulator is being evaluted for possible use in the water infiltration and percolation studies.

Table 2-1 Soils Mapped on the Study Watershed Sites

Soil Identification	Soil Type	Hydrologic Soil Classification	Study Watersheds (Slope - Erosion Classes)				
			A06	C06	M09	J11	J08
Ah	Allegheny silt loam	B		D1,E1			
Be	Berks silt loam	C				G	
Br	Berks shaly silt loam	C	C2,E2,F2				
Bs	Berks channery silt loam	C			G2		
Bt	Brookside silt loam	C			C2,D2		
Cl	Clarksburg silt loam	C		E1			
Co	Coshocton silt loam	C		E1,F1	D2	C2,D2	
Cr	Coshocton-Rayne Complex	C	D2,F2				
Cu	Culleoka silt loam	C				F2	
Dk	Dekalb channery sandy loam	B	C2,D2,E2,F2				
Dl	Dekalb loam and sandy loam	B		F1,G1			
El	Elba silty clay loam	C			C2,D2,F6		
Em	Elba silt loam	C					F1
Gi	Gilpin silt loam	C		C1,D1,E1,F1	C1,C2	C2,D2	B2,C2,D2,E1
Gr	Guernsey silt loam	C					E1
Jo	Johnsburg silt loam	D		C1			

Table 2-1 Soils Mapped on the Study Watershed Sites (Cont'd)

Soil Identification	Soil Type	Hydrologic Soil Classification	Study Watersheds (Slope - Erosion Classes)				
			A06	C06	M09	J11	J08
Kp	Strip Mine Spoil, Acid Fine Loam Skeletal	None					C2,E2,G
Lo	Lowell silt loam	C			E6		
Mo	Monongahela silt loam	C		D1			
Ms	Muskingum silt loam	C		D1,G1			
Or	Orville silt loam	C			*		
Ra	Ramsey sandy loam	B			E2		
Re	Rayne silt loam	C	C2				
Tl	Tilsit silt loam	C			C2		
Up	Upshur silt loam	C			F2		
Ur	Upshur clay	D			D2,E2,E3		
Wd	Wayland silt loam	C/D		*			
We	Westmore silt loam	C			C2,D2		
Wf	Westmoreland silt loam	C			C2,E2		
Wl	Wellston silt loam	B			C2,D2		
Wt	Woodsfield silt loam	C			E2		

Soil Symbols - Soil symbols shown on maps consist of a two letter soil identification followed by a letter code for slope and, lastly, by a number code for erosion. Slope and erosion legends are shown in Table 2B.

* Indicates the soil is present, but no slope or erosion codes given in soil survey.

Table 2-2 Slope and Erosion Codes.

Slope Legend

On Soils		On Spoil	
Code	Slope %	Code	Slope %
A	0-2		
B	2-6	B	0-6
C	6-12	C	6-12
D	12-18		
E	18-25	E	12-25
F	25-35		
G	35	G	25

Erosion Legend

Code	Erosion
1	mostly top soil
2	mixture of topsoil & subsoil
3	mostly subsoil
6	slippage

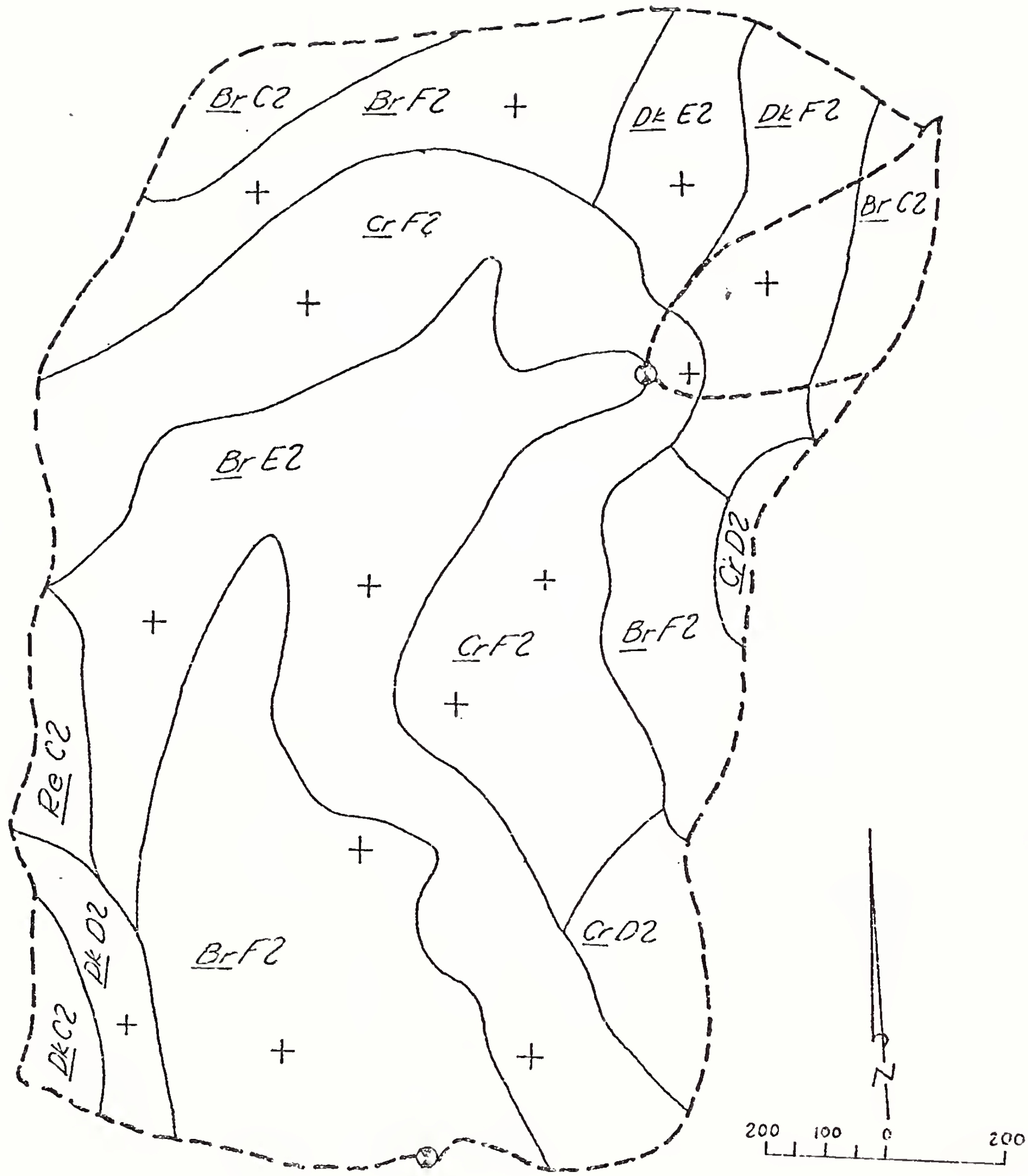

FIGURE 2-1. SOILS MAP FOR WATERSHED A06 (MUSKINGUM COUNTY) AND LOCATION OF SOIL MOISTURE ACCESS TUBES (+)

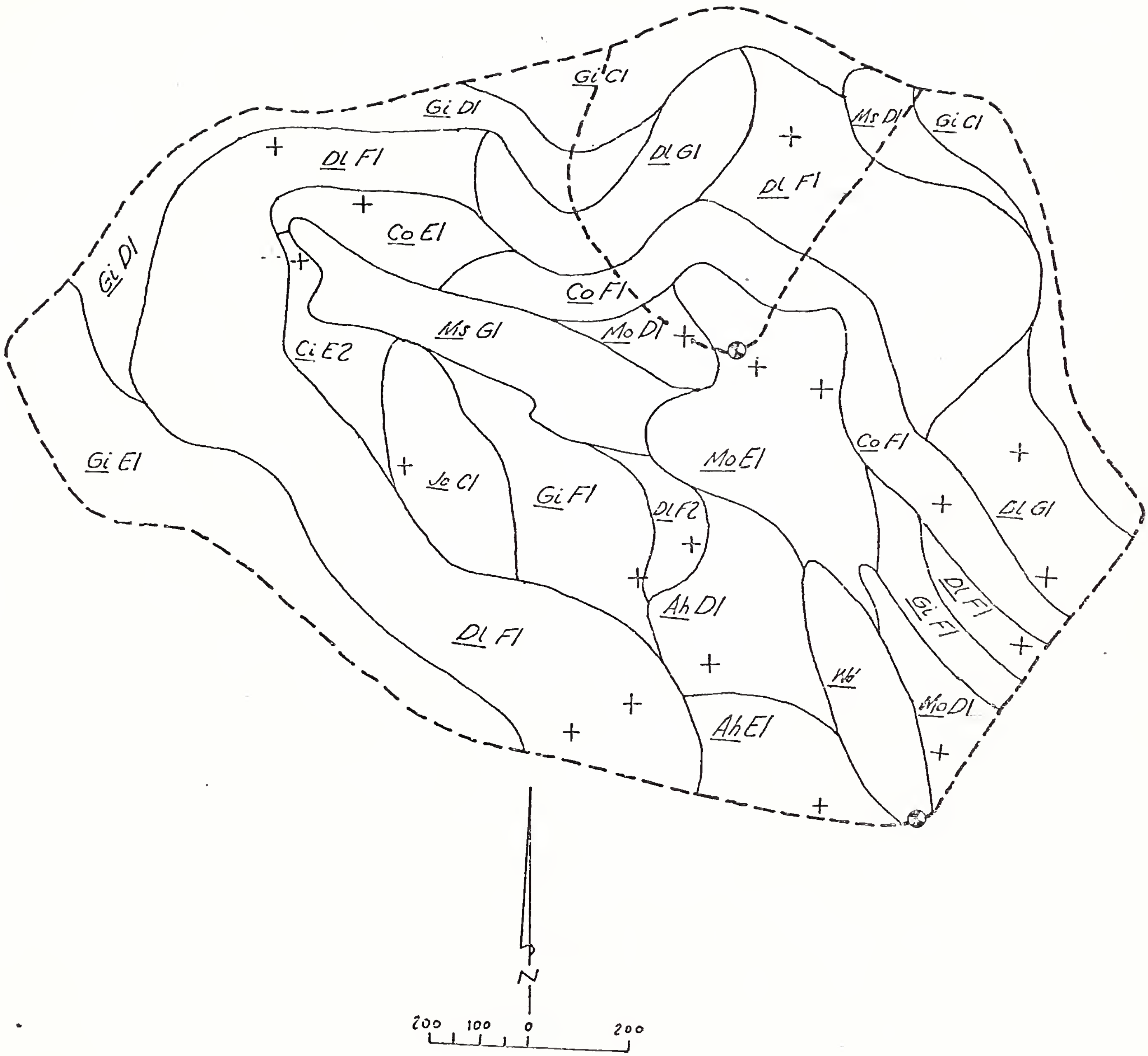

FIGURE 2-2. SOILS MAP FOR WATERSHED C06 (COSHOCTON COUNTY) AND LOCATION OF SOIL MOISTURE ACCESS TUBES (+)

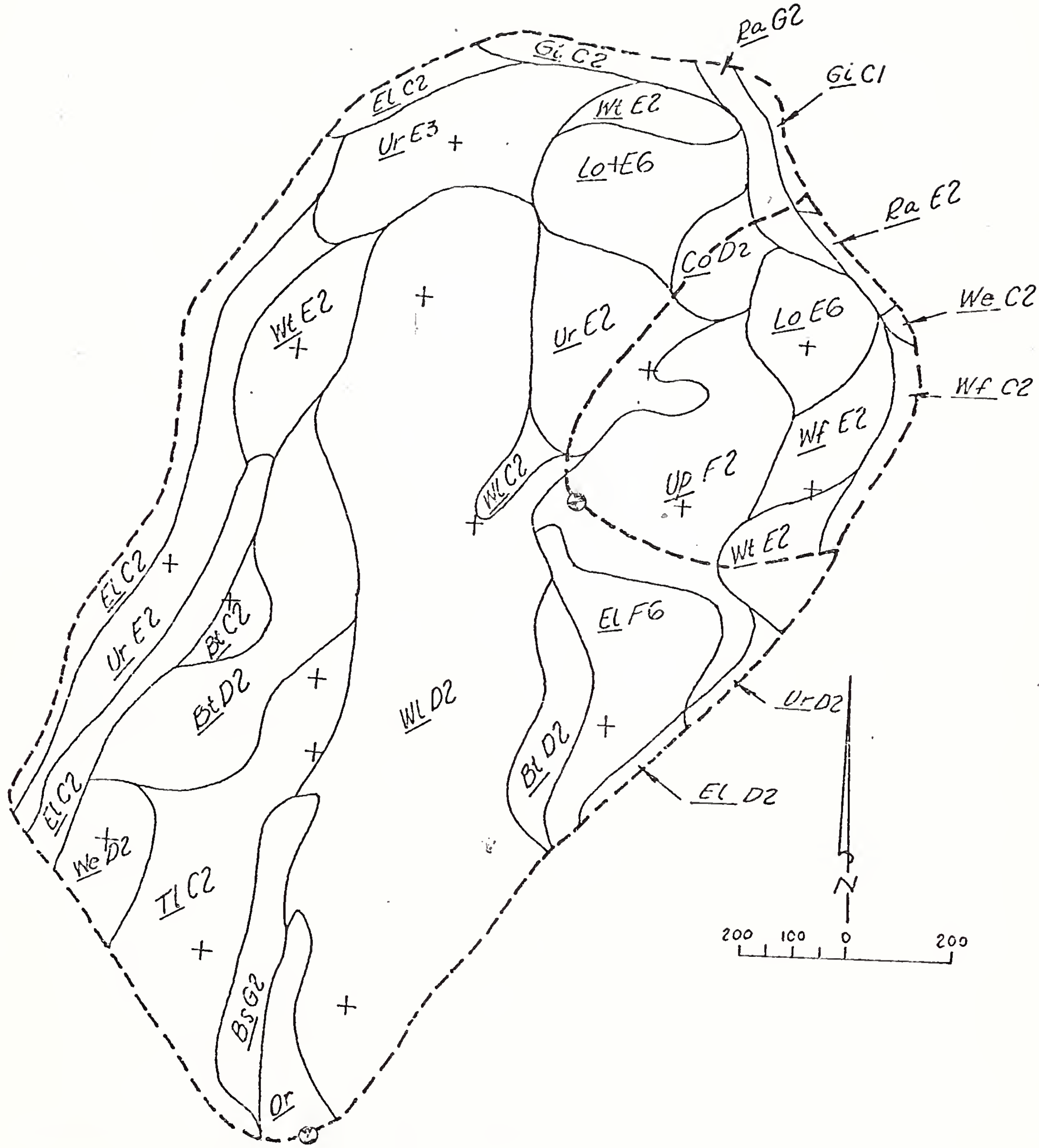

FIGURE 2-3. SOILS MAP FOR WATERSHED M09 (MUSKINGUM COUNTY) AND LOCATION OF SOIL MOISTURE ACCESS TUBES (+)

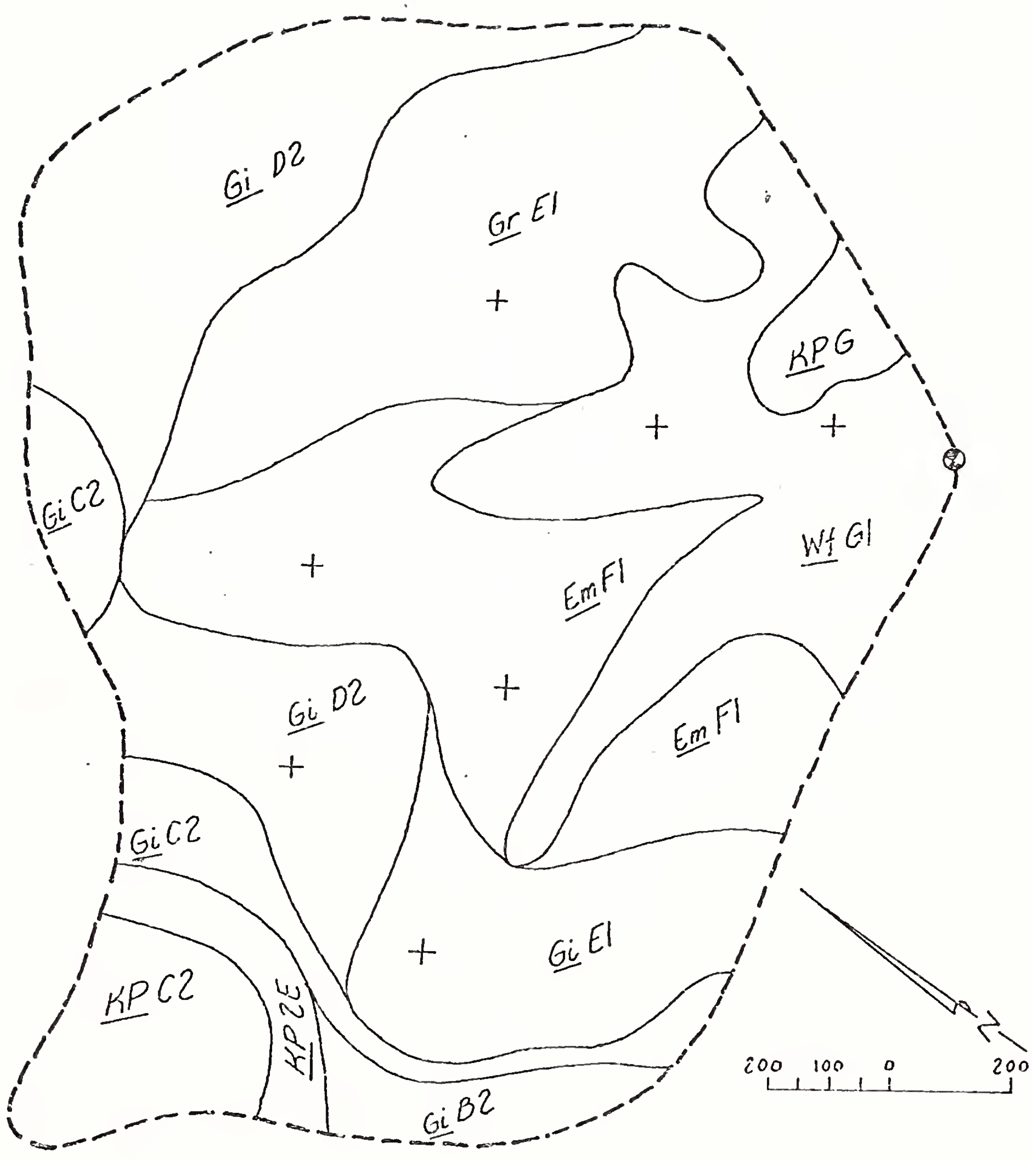

FIGURE 2-4. SOILS MAP FOR WATERSHED J08 (JEFFERSON COUNTY) AND LOCATION OF SOIL MOISTURE ACCESS TUBES (+)

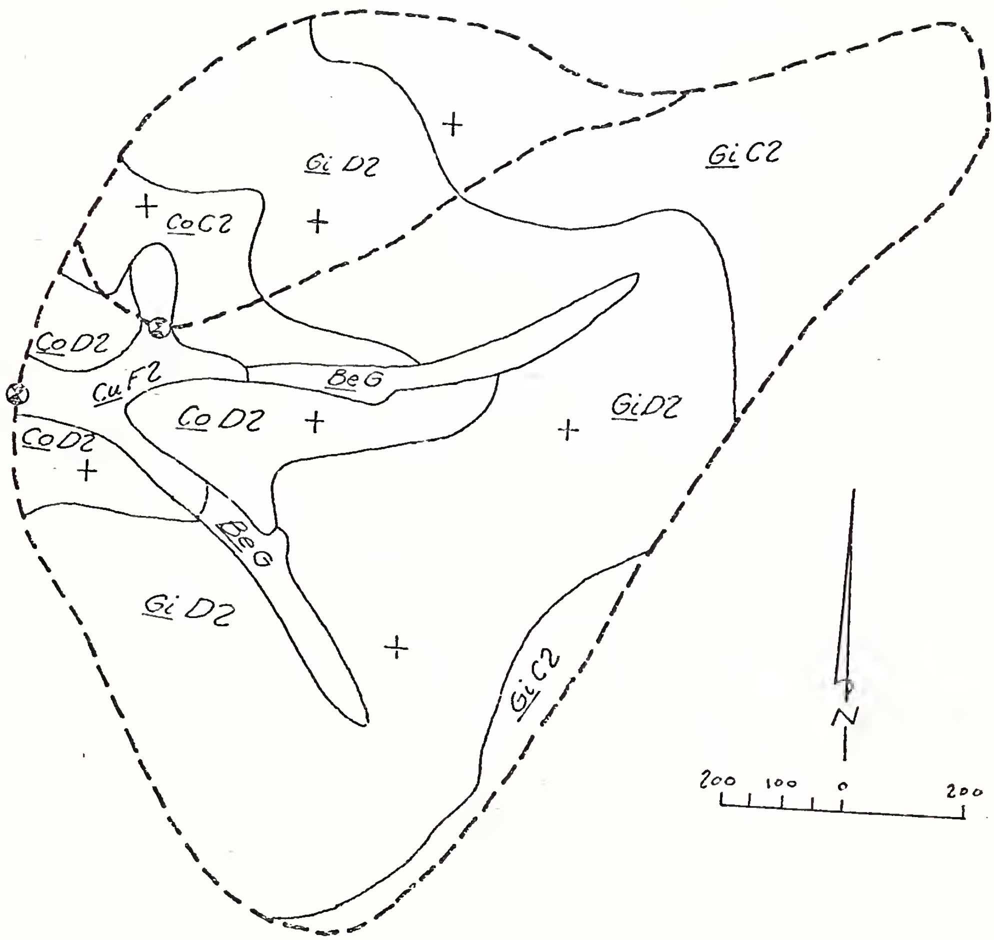

FIGURE 2-5. SOILS MAP FOR WATERSHED J11 (JEFFERSON COUNTY)
AND LOCATION OF SOIL MOISTURE ACCESS TUBES (+)

RESEARCH ACTIVITY
(Semi-Annual Report, August 1976)

(USGS) SM 3-01

Title: Research on the hydrology and water quality of watersheds subjected to surface mining.

Personnel Involved: Darwin Knochenmus and Kristine Rebholz-Ukayli, USGS

Initiation Date: January 22, 1976

Termination Date: January 22, 1981

Objective 3: Describe the hydrogeology of the watersheds and the water quality characteristics of the aquifer systems for pre- and post-surface mining conditions, and develop or adopt a ground-water chemical transport submodel for simulation of the ground water flow conditions and movement of solutes for pre- and post-surface mining condition.

Task No. 1:

Core drilling

Progress Report: Cores were drilled and the identification of the coals and underlaying clays or shales were made so as to facilitate control in the construction of observation wells. In each of the study sites, three aquifers were defined with respect to stratigraphic information obtained from the geologic cores.

At the C06 site, the first aquifer was defined as being the sands, shales, and siltstones above the Middle Kittanning (No. 6) coal, with the underclay acting as the impermeable boundary between the first and second aquifer. The second aquifer was located between this underclay and the clay of the Brookville (No. 5) coal-that aquifer being composed of sand, siltstone, shale and limestone. The Putnam Hill limestone and the Brookville coal and clay were not in the well drilling logs. The third aquifer was the shale and sandstone below the Brookville to the Bedford coal underclay.

The first aquifer at the M09 site consisted of the limy shales, sandstone and limestone to the Meigs Creek, Sewickley (No. 9) coal underclay. The second aquifer was comfined between the No. 9 and the Pittsburgh (No. 8) coal and clay and consisted chiefly of various shales. The lower aquifer was a mixture of clay-shales and limestones.

Both J08 and J11 had very little underclay to serve as an impermeable boundry between aquifers. At J08 the top aquifer, mostly limestone and shales, extended to the Sewickley (No. 9) coal; the second aquifers to the tight green shale just beneath the Pittsburgh (No. 8) coal; and the third extended on down through the shales. The first aquifer at J11 was in sandstone down to the Waynesburg (No. 11) coal. The second aquifer was in shales and limestone to the Sewickley (No. 9) coal, and the third bottomed in the shale beneath the Pittsburgh (No. 8) coal.

The A06 site was similar to the C06 in that the boundaries of the aquifers were defined at the Middle Kittanning (No. 6) coal, the Brookville coal, and the Middle Mercer coal.

Task No. 2:

Observation well drilling

Progress Report: Observation wells were constructed in each of the three defined aquifers in each of the watersheds. On the C06 site, 10 wells were constructed with 4 in the first aquifer, 4 in the second, and 2 into the third aquifer. A total of 11 wells were drilled on the M09 site, 4 in the first, 5 sampling the second and 2 in the third aquifer. At the J08 site, 5 wells were drilled but 2 were abandoned because they ran into old mine shafts. There is 1 well in each aquifer on this limited data watershed. J11 site has 9 wells: 4 in the first aquifer, 3 in the second, and 2 in the third aquifer.

The watershed that is not to be strip mined, A06, has 11 wells: 4 sampling the first aquifer, 5 in the second, and 2 wells in the third aquifer.

Of this total of 44 observation wells, 1 well on C06 needs redrilling because of caving, 1 well in the first aquifer of A06 is dry, and the 2 wells in the third aquifer on the J11 site appear to connect with an abandoned underground mine.

Digital recorders to measure water level fluctuations have been installed in two wells at the C06 and M09 site. The recorders measure hourly water levels in the first and second aquifer at each of the watersheds.

Task No. 3:

Data collection

Progress Report: Water level measurements have been made at each well on every site on a monthly basis since construction of the wells. Typical depths to water in the first aquifers of some sites are: C06, 86 feet to water, 132 feet deep; M09, 65 feet to water, 90 feet deep; J08, 60 feet to water, 125 feet deep; J11, 57 feet to water, 61.5 feet deep; and A06, 84.50 feet to water, 90 feet deep.

Quarterly water samples have been collected twice on the C06 site and an incomplete series once on the M09 site. New pumping equipment and techniques will make the complete sampling possible. Besides the wells on the sites, two springs on C06 and one of M09 are included in the sampling scheme. Results of the physical and chemical parameters tested on C06 indicate that the waters from the three individual aquifers appear to differ slightly. Generally, the first aquifer had a lower total hardness and specific conductance and a higher pH than the second aquifer with all values ranging between a pH of 6.5 to 6.8, total hardness between 95 to 320 mg/1 and specific conductance between 290 and 860 micromhos. The third aquifer had the lowest of all three parameters: pH, 6.6; total hardness, 120 mg/1; and specific conductance 258 micromhos.

Gamma and electric geophysical logs have been run on nine wells on C06 and on all wells on M09.

Aquifer characteristics will be determined by future aquifer pumping tests.

Task Nos. 4, 5, 6 & 7:

(See Research Plan and Activities, July 1976)

Progress Report: The data analysis and post-mining data analysis of Task 4 through Task 7 will be approached with completion of the pre-mining data collection.

RESEARCH ACTIVITY (ARS) SM 4-01
(Semi-Annual Report, August 1976)

Title: Research on the hydrology and water quality of watersheds subjected to surface mining

Personnel Involved: Daniel I. Carey, W. Russell Hamon and James V. Bonta, ARS

Initiation Date: January, 1976

Termination Date: January, 1981

Objective 4: Develop or modify a computer model for simulation of the hydrologic and water quality regimes of the study watersheds for both pre- and post-surface mined conditions by incorporating mathematical representations of sub-models for the water flow components and sediment and chemical transport with emphasis on selection of model parameters that can be reasonably acquired for non-study areas within the physiographic region for application of the model.

Task No. 1:

Develop or modify a computer model for simulation of watershed hydrologic and water quality components for pre-mining conditions.

Progress Report: A number of methods for modeling surface water hydrology have been examined. In order to represent the heterogeneous surface for both pre- and post-mined conditions, the watershed will be modeled by a number of relatively homogeneous surface units. The length of these units will equal the length of the standard erosion plots (72.6 feet long) in order to attempt to physically model the erosion processes using the data from the plots.

It is felt that the overland routing of storm runoff on the units can be satisfactorily modeled by ordinary differential equations. This will keep the computation costs down and allow the model to be programmed in a simulation language, if desired. The simulation language SIMSCRIPT II.5 has been examined for this purpose. This language is widely available and is structured so that the flow of logic in the model program should be easily understood, allowing modifications to be made to the program with a minimum of effort. The latter feature is quite important if the model is to be widely used and represent a variety of situations.

Procedures to represent infiltration and redistribution of water in the soil have been examined. Numerically solving the unsaturated porous media flow equation does not seem to be feasible due to data and computation requirements. The use of any one of the conceptual or empirical infiltration equations (Horton, Holtan, Green-Ampt, Philip, Kostiokou) seems to be a matter of personal preference. The watershed model will be structured so that any infiltration routine of this type can be used. Presently it is felt that a simple storage-response function analogous to a series resistance-capacitance network (Hortran-type equation) will be used. Parameters for the function will be derived from rainfall simulator tests for the different surface conditions.

At this level of development the model might serve as a basis from which to study the effects of surface mining and reclamation procedures on surface runoff phenomena. Probable changes in stormwater runoff peaks and volumes and sediment loads could be determined, for example, by using probability models of soil moisture and rainfall with the stormwater model.

In order to continuously model the watershed hydrology, the evapotranspiration, percolation, and groundwater components must be added to the stormwater model. The evapotranspiration component will be modeled by using the aerodynamic and energy budget equations together with a surface resistance representation of the Bowen ratio. Methods for modeling the redistribution of soil moisture and percolation of water from the root zone to groundwater are presently being considered.

Task No. 2:

Modify or adjust computer model for simulation of post-mining conditions of runoff, sediment yield and water quality with incorporation of groundwater model as developed under Objective No. 3.

Progress Report: A discussion of modeling procedures was held with USGS hydrologists on the project and no problems were anticipated in interfacing the ground and surface models as proposed.

Task No. 3:

Utilize the watershed model to simulate the response of the study watersheds over a full range of climatological conditions and for different reclamation treatments.

Progress Report: To be undertaken at a later date following the availability of a suitable operational model.

RESEARCH ACTIVITY (OARDC) SM 5-01
(Semi-Annual Report, August 1976)

Title: Research on the hydrology and water quality of watersheds subjected to surface mining

Personnel Involved: William Wayt, OARDC

Initiation Date: January 22, 1976

Termination Date: January 22, 1981

Objective 5: Determine costs to obtain the necessary physical, chemical and hydrologic data, including legal and administrative costs, as required for surface mining permits as well as costs for obtaining these data at alternate degrees of accuracy and completeness; and determine costs and benefits of alternative degrees of control of runoff, sediment and water quality.

Task No. 1:

Estimate legal and administrative costs of obtaining necessary data required to obtain mining permits.

Progress Report:

Core Drilling Costs

Applications for mining permits typically require a report of test boring holes in the area to be mined. Reports are to include location of bore holes, nature and depth of overburden and material underlying the coal seam, thickness of seam and crop line of the seam. Costs of obtaining the necessary test borings will vary with the number required, depth of test boring, and relevant prices or rates of payment.

For the current research project five cores were obtained. Three were obtained under one contract, one under another contract, and one provided at no charge by a cooperating mining company. Some measure of the variability of cost is indicated by the total cost of three 2-inch cores, for an average depth of 272 feet, under the one contract which amounted to $8,365, or less than $2,800 each, for an average of $10.25 per foot of core. The cost of the other contracted 2-inch diameter core was $7,800 or $16.32 per foot of core for the 478 feet of core. In the latter case, the drillers were working on a daily basis; whereas, in the former, the contract was in terms of a flat rate per set-up plus a fixed rate per foot of core drilled.

The basic cost elements in the contract with one contractor were: $300 flat rate per hole for a set-up, $8.60 per foot of core drilled, standby time at the rate of $42.00 per hour for rig and crew, and $4.50 per sack of cement used for grouting of the drill hole.

Water Well Costs

At the five watershed sites a total of 43 wells were drilled to provide for obtaining water samples and elevation of ground-water tables. Basic prices in the well drilling contract were $6.00 per foot of open 6-inch hole and $12.00 per foot of cased 6-inch hole (the latter including cost of grout and casing). An additional $50.00 per hour price was charged for cleaning and development of the well. Provisions relative to payments for abandoned wells, possible reuse of casing, and terms of cost responsibility are contract details; however, it appears that a two percent add-on cost might be a good basis of estimation. (One well needed to be abandoned in this group of wells drilled.) This group of 43 wells cost over $53,000 or approximately $1,250 per well on the average. The total footage of wells drilled was 5200 feet with 2096 feet for a 6-inch casing and 3104 feet below casing into bed rock. A total of 1900 feet of casing were used in the wells. The average well depth was 121 feet and the average cost per foot was $10.33.

Task Nos. 2, 3 and 4:

(See Research Plans and Activities, July 1976)

Progress Report: Estimates of costs and benefits will be made as project data becomes available.

RESEARCH ACTIVITY (ARS) SM 6-01
(Semi-Annual Report, August 1976)

Title: Research on the hydrology and water quality of watersheds subjected to surface mining

Personnel Involved: W. R. Hamon, ARS
P. Sutton, OARDC
D. Knochenmus, USGS

Initiation Date: January 22, 1976

Termination Date: January 22, 1981

Objective 6: Submit semiannual status reports, study phase reports and a final project report with documentation of research data and results, and cooperate with the Bureau of Mines in interpreting such data and results.

Task No. 1:

Prepare semiannual and study phase (1. pre-mining, 2. mining, and 3. post-mining) reports. (ARS-OARDC-USGS)

Progress Report: This report constitutes the first Semi-Annual Technical Report for the project. The Phase 1 Report of pre-mining hydrologic and water quality conditions will be submitted in December 1977.

Task No. 2:

Prepare final report and confer with Bureau of Mines to assist in interpretation of data and results. (ARS-OARDC-USGS)

Progress Report: Report to be submitted at termination of project.